United States Department of Agriculture

Agricultural Research Service

Solving Agricultural Problems With Biotechnology

Solving Agricultural Problems With Biotechnology

Several new technologies are emerging from recent research in the biosciences, particularly the advances in molecular biology of the 1960's. And the Agricultural Research Service (ARS), the principal research arm of the U.S. Department of Agriculture, is using and developing these new technologies to help find solutions for some of the most vexing and intractable problems facing U.S. agriculture.

Called biotechnology, this still-growing field now offers unprecedented opportunities to study and understand fundamental life processes and to modify and regulate these processes precisely. Application of this knowledge can be used to solve problems, produce new products, and provide other economic and social benefits.

But biotechnology is broader than just genetic engineering or gene splicing. It also includes tissue, cell, and embryo culture; protoplast fusion; bioregulation or hormonal control of physiological and metabolic processes; and production of gene-controlled products.

Already, more than 400 commercial firms, large and small, are either directly or indirectly using biotechnology research to solve problems in food production, medicine, and pharmacology.

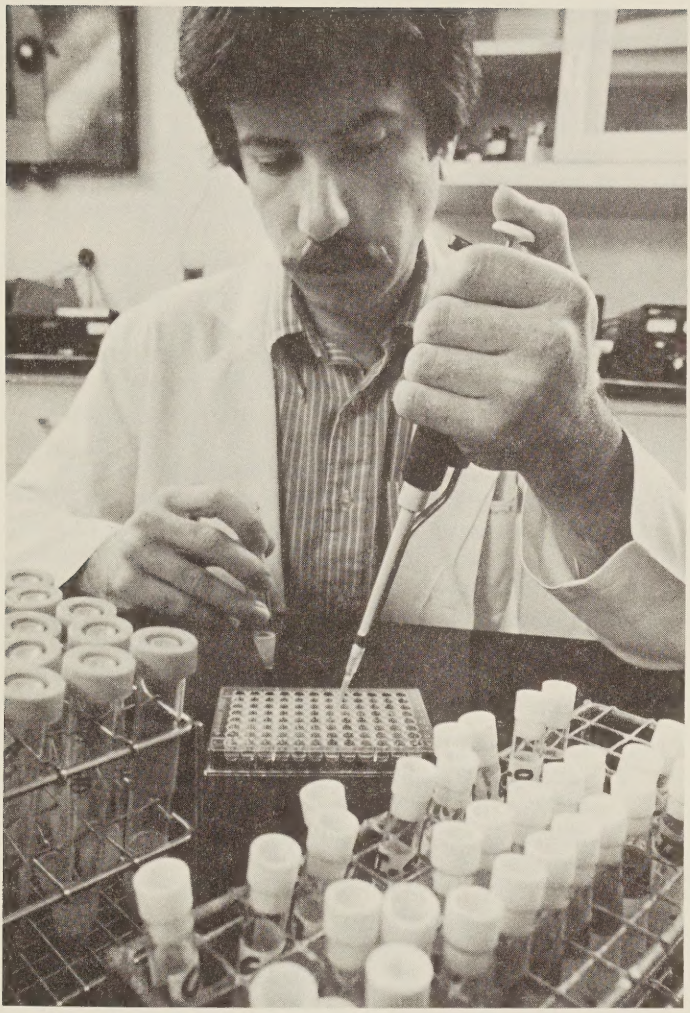
And in agriculture, the world's largest and most important industry, use of biotechnological tools and methods can help solve many problems—indirectly by enabling researchers to know, with a precision never before possible, the basic processes that make things happen in plants, animals, and humans; directly by providing the mechanisms that allow selective, precise, beneficial manipulation of these processes.

Biotechnology in the Agricultural Research Service

ARS is using biotechnology research throughout much of its total program as part of its arsenal of tools in fulfilling its specific missions and program goals.

In contrast to the trend at many universities and in the private sector, ARS does not concentrate its biotechnology research at specific centers, nor does it plan to do so. In fact, the 5 percent of the ARS fiscal year 1985 funding specifically devoted to biotechnology research is distributed among 200 scientists at 41 locations.

Cover: ARS geneticist mapping the genes of a soybean protein.



ARS zoologist preparing to test pig serum for trichinosis. A product of monoclonal antibody techniques, the test was developed as a tool for studying the mechanism of immunity, but it can also be automated and adapted for commercial use in meatpacking plants.

ARS' ongoing biotechnology research is directed toward the solution of high-priority agricultural problems of national scope. These include conserving and maintaining the quality of natural resources; reducing high costs of farm production, improving crop protection and production efficiency, and enhancing market value and quality of farm products; overcoming technical barriers to marketing and export of agricultural products; and promoting human health and well-being through nutrition.

ARS defines these problems through interaction with industry groups, other Federal and State agencies, and the scientific community. Approaches to solving the problems are developed by ARS researchers and its National Program Staff.

Some of the specific problems selected by ARS lend themselves to biotechnological solutions; in other cases, traditional technology might prove to be the better choice.

For example, the sugar content of cane might be increased by traditional breeding for higher yielding strains; use of a synthetic plant-growth regulator to enhance sugar accumulation; or identification, cloning, and transfer of one or more genes and their products to amplify the enzyme systems that synthesize sugar.

But whatever approaches are chosen for the specific problems, biotechnology promises to speed up the overall research process and, in many cases, provide new tools and technologies for implementing even traditional research approaches and enhancing existing scientific information.

Among the biotechnological techniques and tools that might be used to help solve agricultural problems are—

- Controlled bioreaction and bioreactor research to improve the quality and processability of food, convert plant and animal material to more valuable new products, biosynthesize physiologically active compounds, and control intermediary metabolic and anabolic reactions.
- Cell, tissue, organ, embryo, and organelle (including subcellular particles) culture to clone genes, express totipotency, produce secondary metabolites, decode developmental programs, develop regulatory molecular and mechanistic functions, determine what factors limit physiological functions and desired component formation, and control senescence.
- Recombinant DNA techniques and associated research on gene-transfer vectors and gene products to enhance desired characteristics of plants, animals, and microbes and eliminate their undesired characteristics; control expression of desirable or undesirable gene functions; transfer genetic material for production of such specific materials as microbial antigens or enzymes for food processing or bioconversions; and transfer genetic material for increased microbial-process efficiency.

- Hybridoma research to provide discrete gene products, as required, and isolate and preserve discrete genes, gene sequences, or chromosome fragments in functional condition.
- Genetically engineer viral and microbial insect pathogens for improved and more economical insect control.

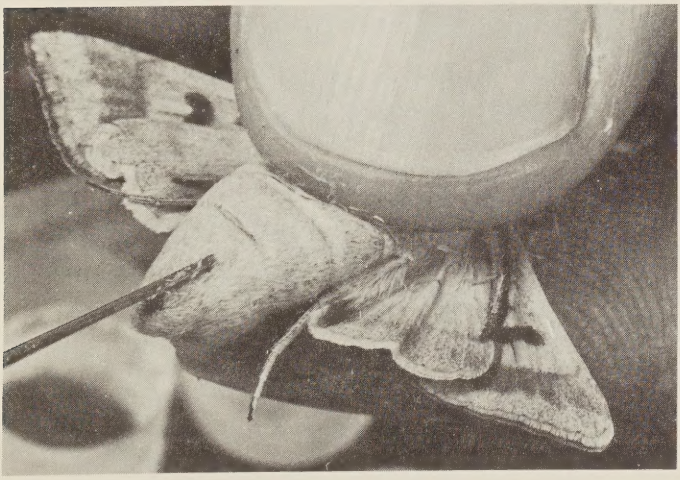
ARS Research Using Biotechnology

ARS currently allocates about $26.7 million to research involving biotechnology: $227,000 (1 percent) to soil and water management and conservation; $10.2 million (38 percent) to plant productivity and protection; $8.8 million (33 percent) to animal production and protection; $7.4 million (28 percent) to product quality and use for domestic and export markets; and $51,000 (less than 1 percent) to human nutrition.

ARS is carrying out 165 research projects involving extensive use of biotechnology. Among these are the following examples.

To help solve problems in soil and water conservation and management, ARS researchers are using biotechnology to—

- Develop sensitive diagnostic tests for detecting small amounts of chemical residues in soil and water.
- Bioengineer soil bacteria to degrade chemical contaminants in soil and ground water.



Injecting homogenized extract of corn earworm brains into a ligated female. This research revealed that a neurohormone controls production of the sex pheromone used by the female to attract and sexually activate the male.

To help solve problems in plant productivity and protection, ARS researchers are using biotechnology to—

- Identify plant enzymes and genes that code for them involved in regulation of the partitioning of carbon distribution among plant parts. After determining what genes are involved and their physiological mechanisms, researchers can discover how to control partitioning and begin to bioengineer plants for more efficient carbon distribution patterns to increase yields of edible plant parts.
- Improve *Rhizobium* bacteria genetically for enhanced nitrogen-fixation activity in legume crops and transfer nitrogen-fixation genes to nonleguminous crops that now lack this ability.
- Identify the genes coding for enzymes that synthesize insect neurohormones and neuropeptides; with more of these available for study, researchers will be able to examine and elucidate their structure to discover possible new approaches to insect control.
- Bioengineer plant pathogens to increase their effectiveness as agents for biological control of weeds. For example, with recombinant DNA technology, it may be possible to increase the pathogenicity of several marginal plant-pathogen isolates by multiple gene insertion or by gene amplification to make them more effective weed pathogens.

To help solve problems in animal production and protection, ARS researchers are using biotechnology to—

- Identify and transfer genes in livestock species to enhance lean muscle growth and to improve quality of meat and dairy products.
- Develop reliable methods of transferring and cloning embryos.
- Develop and improve vaccines, through recombinant DNA technology and use of monoclonal antibodies, for various economically devastating animal diseases, such as foot-and-mouth disease, brucellosis, and coccidiosis.
- Develop sensitive diagnostic methods, using monoclonal antibodies and gene probes, to replace those that require slaughtering animals to detect such livestock diseases as trichinosis in swine and bluetongue in sheep.

To help solve problems in product quality and use for domestic and export markets, ARS researchers are using biotechnology to—

- Improve functional quality of varietal wheat-storage proteins by studying wheat protein composition and quantity at the molecular level and identifying the genes that regulate protein synthesis. Manipulation of these genes with biotechnological techniques is more direct than seeking random mutation or recombination through breeding. Success in controlling wheat protein ratios should improve U.S. competitive position in wheat export markets with higher quality products.
- Bioengineer bacterial enzyme systems to convert plant-derived oils to chemical feedstocks for entry into new markets.

To help solve problems in promoting human health through nutrition, ARS researchers are using biotechnology to—

- Discover through elucidation of the molecular structure of cell membranes what controls the interactions of lipoproteins and their cellular receptors. These interactions are essential to metabolic processes required for good health.
- Study, through dietary regulation of peptide hormone receptors, how various nutrients can influence glucose tolerance and the production of lipids.

The ARS Commitment to Biotechnology Research

The experience of the Agricultural Research Service with biotechnology goes back decades, long before the concept got its name. One ARS milestone in biotechnology was the deciphering of the molecular structure of a ribonucleic acid (RNA) by a team of Agency and Cornell University scientists. That achievement won the research team's leader, Robert W. Holley, a share of the 1968 Nobel Prize for medicine or physiology.

Other examples of ARS achievements in biotechnology include—

- A vaccine against foot-and-mouth disease, developed through recombinant DNA technology in collaboration with Genentech, Inc.
- A vaccine against Marek's disease of poultry, developed with cell-culture techniques.
- A genetically engineered antigen, developed in cooperation with Genex Corp., that helps protect chickens against one parasite that causes coccidiosis. This could lead to a vaccine.
- New rice plants, developed through tissue culture, with more and better quality protein.

- Discovery of movable gene elements in soybeans that may prove an important key to genetic engineering of economically valuable plants.

The experience represented by these achievements is the foundation for the Agency's increased commitment to use of biotechnology in its research. The interdisciplinary teams involved in biotechnology research can rely on the expertise of men and women who have been using and developing these tools for years.

Building the future on the success and experience of the past, ARS has also nearly doubled the number of postdoctoral scientists on 1- or 2-year appointments in its elite Research Associates Program. These scientists will concentrate mainly on biotechnology projects in the animal and plant sciences.

In its biotechnology research as in its other research projects, ARS seeks to make the most efficient use of its resources and of its formal cooperative relationships with universities and the private sector.

For instance, current efforts to build gene libraries for major plant commodities are so broad that they require extensive cooperation with several university laboratories. Scientists and research leaders coordinate the technical effort, and the ARS National Program Staff coordinates the interaction of ARS program areas and oversees research progress.

Long-Range Goals for Biotechnology Research in ARS

ARS is making major efforts to find ways to culture single cells from many crop plants and to regenerate them into whole organisms with the genetic message intact and properly expressed. In animals, embryonic single cells—the fertilized egg—may well be the recipients for gene transplants. Modern techniques of embryo recovery, splitting, and transfer are playing critical roles in genetic engineering efforts.

Issued August 1985

☆ U.S. GOVERNMENT PRINTING OFFICE: 1985 - 528-894 - 814/30851